# EFFECT OF CLAMPING DISTANCE AND VOLTAGE ON WELDABILITY OF DISSIMILAR WELDING

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## ABSTRACT

In welding technology, there are a lot of parameters that would give different effects on the weldability, specifically in welding of dissimilar metal. In this study, carbon steel and stainless steel are welded by using metal inert gas welding or MIG by using ER308 filler wire and the parameters involve in this study are clamping distance and voltage. The objectives of this study are to study the effect of clamping distance and voltage on dissimilar welding and to determine which clamp is the most suitable in improving weld quality. The output for this study is focusing on the defects caused by different parameters and the hardness on the fusion zone. In this study, the current and speed is kept constant throughout the experiment. This study involves the microstructural preparation which involves the mounting, grinding, polishing, and finally the etching process in order to perform hardness test. Visual inspection is done by using naked eyes to determine the defects caused by different parameters. Comparison on the weld quality of sample welded by using same parameters including voltage is done to find out how different clamping distance would affect the weld quality. Parameter optimization is done by using Taguchi Method and Analysis of Variance is used to determine the most significant parameter that affects hardness at the fusion zone. From the analysis, the highest hardness value and minimum defects can be seen visually is on sample welded by using 21 V and 3.75 cm distance of clamping, which is by using clamp 2. The most significant parameter that affects the hardness is the distance of clamping. Confirmation test is done at the end to validate the result of experiment.

## ABSTRAK

Dalam teknologi kimpalan, terdapat banyak parameter yang akan memberi kesan yang berbeza pada kebolehkimpalan, khususnya dalam mengimpal logam yang berbeza. Dalam kajian ini, keluli karbon dan keluli tahan karat dikimpal dengan menggunakan kimpalan gas lengai logam atau MIG dengan menggunakan dawai pengisi ER308. Parameter yang terlibat dalam kajian ini adalah jarak pengapitan dan voltan. Objektif kajian ini adalah untuk megkaji kesan jarak pengapitan dan voltan atas kebolehkimpalan dua logam yang berbeza. Kajian ini juga adalah untuk menentukan apit yang sesuai dalam menaiktaraf kualiti kimpalan. Output kajian ini bertumpu kepada kecacatan dan kekerasan pada titik tertentu yang disebabkan oleh parameter yang berbeza. Kajian ini melibatkan penyediaan untuk menganalisa mikrostruktur dan ujian kekerasan. Pemeriksaan visual dilakukan dengan menggunakan mata kasar untuk mengenalpasti kecacatan yang disebabkan oleh parameter yang berbeza. Perbandingan dari segi kualiti kimpalan pada spesimen yang dikimpal dengan menggunakan parameter yang sama termasuk voltan yang sama dilakukan untuk mengetahui bagaimana jarak pengapitan menjejaskan kualiti kimpalan. Kaedah Taguchi digunakan dalam menentukan parameter optimum dan ANOVA digunakan untuk mengenalpasti parameter yang memainkan peranan penting dalam menentukan nilai kekerasan. Berdasarkan daripada analisis data, nilai kekerasan yang tertinggi dan kecatatan minimum adalah pada sampel yang dikimpal pada 21 V dan pada jarak 3.75 cm, di mana apit yang digunakan adalah apit ke-2. Parameter yang memberi lebih banyak kesan kepada nilai kekerasan adalah jarak pengapitan. Akhir sekali, ujian pengesahan dilakukan dengan menggunakan parameter optimum untuk mengesahkan nilai kekerasan dan kecacatan yang dapat dilihat secara visual

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# CHAPTER 1

# INTRODUCTION

## 1.1 RESEARCH BACKGROUND

Welding is a process of joining metal which is widely used in the sector of manufacturing of most engineering and structural machineries. Welding is a joining process with a simple set up, high joint efficiency and low cost of fabrication. (Chin-Hyung Lee, 2012). In order to obtain good weld joint strength of sheet metal, it is essential to have a good clamping device.

Welding jigs are device that enables material to be easily and rapidly setup and held. Welding jig is designed and fabricated for the purpose of holding parts in alignment and to ensure accurate fit-up with no need for tack welding (Alber A.SADEK, 2000).Welding jigs or fixtures are used in holding parts to be assembled in a correct position for welding. There are differences between welding jigs and tacking tools, where tacking tools are used only when the part is to be tack-welded. Welding jigs are designated to be much heavier compared to tacking tools in order to resist added forces caused by the heat within the part. (G.hoffman).

## 1.2 PROBLEM STATEMENT

In dissimilar welding, there are numbers of technological difficulties arising and one of the methods to overcome the problems is by improving the clamping system. Welding dissimilar metals is normally complex compared to the welding of similar metals (Alber A.SADEK, 2000). Distortion and warping is the main problem during welding and this is caused by the design of the jig itself. Problems in dissimilar welding make the joint to be easily cracked and caused failure. (Yaowu Hu, 2012). This is mainly caused by partial penetration due to inadequate heat dissipation and brittle intermetallic compound.

In designing welding jigs, there are some basic considerations that should be taken such as heat dissipations. It is important to ensure proper heat to be maintained in the weld area and the priority goes to the amount of heat required. Thus, in this research, the effect of clamping, specifically, the distance of clamping is studied to reduce defects in welding.

## 1.3 OBJECTIVES

The objectives of this project are to:

a) To study the effect of clamping distance and voltage on dissimilar welding.
b) To determine the most suitable clamp to be used to improve weld quality.

## 1.4 SCOPES

The scopes of this project are to:

a) Perform experiment on dissimilar welding of stainless steel and carbon steel to study the effect of clamping distance and voltage changes.
b) Perform experiment by using MIG welding machine.

## 1.5 SUMMARY

The study on the effects of clamping distance and voltage on weldabilty of dissimilar welding is presented in this thesis and is organized into five chapters. The first chapter had discussed on the project background, problem statements, objectives and the scopes related to the study. The next chapter, Chapter 2 will discuss on the literature review of the project and it will be focusing on the recent study that approximately related to the title. It is an important in order to obtain predicted outcome in this study and it is in form of book, articles and journals. Chapter 3 will gives the research methodology, the design of experiments, tools and equipment involve in the study. Chapter 4 will be presenting the data obtain and the analysis of data obtain from the study. Then, lastly the result is summarized in the final chapter, Chapter 5.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter is the literature review on dissimilar welding and the effects of clamping on the weldability on dissimilar welding. This chapter is also about the review on the material involve in the study and process related to study.

## 2.2 PROBLEMS IN DISSIMILAR WELDING

Melting and solidification of weld metals and base metal are the processes that are involved in localized fusion zone which is caused by a transient thermal heat source. Temperature which does not spread uniformly happens on the welded joints and base metal due to confine heating and subsequent cooling (B. Taljat, 1998). Uniform temperature distribution is one of the important aspects to be taken in order to avoid defect in welding.

Dissimilar metal joining is widely used in many products in chemical, petrochemical and nuclear engineering. The application of the dissimilar metal joints does not only limited to the different requirements of various service conditions, such as heat resistance, corrosion resistance and magnetic properties, but it also resulting in large savings of expensive materials, which reduced cost of product. In order to meet design requirements, dissimilar welding is applied (Alber A.SADEK, 2000).

In the process of joining dissimilar material, it is more challenging to study the mathematical reproduction of residual stress if compared to the residual stress in joining similar material. This is caused by the differences in metallurgical properties of the materials to be joined, the physical properties and also the mechanical properties. (E.K. Dimitrios, 2005; S. Nadimi, 2008; D. Akbari, 2009; D. Deng K. O., 2009; D. Deng S. K., 2011).

Partial penetration is one of the problems in dissimilar welding which is caused by different properties, physically and chemically. Those are different in terms of heat capacity, thermal conductivity, thermal expansion coefficient, and temperature where the metal melts. Inappropriate heat treatment in welding of dissimilar welding caused the occurrence of brittle intermetallic compound which caused low strength of joint (H.C. Chen, 2011; Z. Sun, 1995; C.W. Yao, 2009; A. Mathieu, 2007; S. Chakraborty, 2010).

Dissimilar metals are hard to be welded on account of the establishment of brittle intermetallic phases and varied difference in physical and mechanical properties. To obtain good weld join strength, the formation of the solid solution in the weld pool is needed whereas the formation of intermetallic is not needed. It is critical to minimize the thickness of intermetallic phases in the fusion zone (Jokiel, 2006;Van Tienhoven, 2006) (Katayama, 1998). The greatest main issue in dissimilar welding is due to the differences in physical properties of base metals, as well as on certain level of metallurgical incompatibility.

Residual stress from welding is the primary source of deformation in welded panels especially in thin sections. This occurs when the residual stress level exceeds the buckling limit of the weld joint out of plane distortion occurs (Michaleris, 1997). The total stress on a part is the stress from the combination of in-service loads and the residual stress (Price, 2007). Residual stress contributes to diminished fracture resistance (Gachi, 2009). The welding parameters need to be controlled in order to control both geometric tolerances and material properties that are desirable to mitigate residual stress.

## 2.3 GAS METAL ARC WELDING (GMAW)

Metal Inert Gas (MIG) welding is commonly used and accepted slang term that was appropriate when the process was first invented. In the beginning, the gasses used for shielding the weld area were known as "Inert" or "Nobel" gasses. Today, the proper terminology is "Gas Metal Arc Welding" or GMAW. This is the best description since most gasses or gas mixtures used are neither Inert nor Nobel gasses, and in many cases they are actually reactive gasses.

This type of welding is also sometimes refers as "Wire Wheel Welding" because of the usage of wire wheel to feed the filler metal to the weld joint. MIG can weld almost any types of metal and one of the biggest attractions about MIG process is how fast it is able to weld more than just steel. Metals that are commonly welded using MIG welding are mild steel, stainless steel and aluminum. This welding process can weld many more alloys and combination of metals. One common dissimilar welding that is usually done is welding stainless steel to steel. Other metal that can be welded range from copper to titanium. The list of metals that can be welded is extensive and range from very common metals to extremely exotic.

Gas Metal Arc Welding (GMAW) is a once welding process that uses an arc between a continuous filler metal electrode and a weld metal. The process is used with shielding from an externally supplied gas and without the application of pressure; it was developed in the late 1940's for welding aluminum and has become popular. There are numbers of variations depending on the type of shielding gas, type of the metal transfer, type of the metal welded and so on. It has been named MIG welding, $CO_2$ welding, Fin wire welding, Spray arc welding, Pals arc welding, Dip transfer welding, Short circuit arc welding and various trade names. (Phule, 2004). Figure 2.1 shows the MIG welding machine that are commonly used,


**Figure 2.1:** MIG Welding Machine

### 2.3.1 Power Supply and Equipment

MIG welding power supplies are referred as CV or “Constant Voltage” power supplies. The power supply produces electrical current to create arc to weld the metal with. The term CV means that the heat settings are controlled with voltage. When MIG welding, the machine is always set by voltage and this type of power supply keeps the voltage t consistent level.

MIG welding require a wire feed system and this system is what feeds the electrode or filler wire to the weld joint. This is where the “Wire Wheel Welding” comes from. The wire feeds come in many different forms. Some are part of the power supply, and the higher-end models come in stand-alone form or are contained inside a briefcase. He wire feed is regulated in IPM or “Inches per Minute”. This is how the speed of the filler wire is regulated and set. The wire feed system also controls shielding gas and all welding operations that are signaled from the MIG gun. The MIG gun has a handle with a trigger that is attached to the wire feed through a cable. The MIG gun feeds the filler wire, the shielding gas, and electricity to the joint. Once the trigger is hit, the MIG gun shields the weld area from the air, produces the arc and welding process is started by feeding wire to the joint.

### 2.3.2 Shielding Gases

There are many shielding gases used for MIG welding and since the electrodes are solid metal wire, some form of shielding gases from the air is needed. The gases range from inert gases to reactive ones. In many cases, the gasses used are a combination of two or more gasses. Some of the commonly used gasses are argon, carbon dioxide, helium (in rare cases) and oxygen (in small percentages).

For most welding applications, combination of Argon and Carbon Dioxide are used. When it comes to welding gases, Argon produces a lot of smoke while welding. Some of the most commonly used gases for welding carbon steel are 100% Carbon Dioxide, 25% Carbon Dioxide and 75% Argon, and 2% Carbon Dioxide and 8% Argon.

### 2.3.3 Electrodes or Filler wire

MIG/Mag is a flexible and fast method for semi or fully automatic welding. Welding can be performed in all positions and a normal plate thickness would be between 2 and 10 mm. Pulsed arc welding offers the best flexibility and is particularly suitable when high alloyed stainless steel and nickel based filler is used.

## 2.4 CLAMPING SYSTEM

Clamping is the most important system in counteracting welding to induced distortion. Distortion effect increases as the clamp is moved closer to the weld centerline (Shenk, 2009). Distortion is reduced by increasing the clamping force, but above a certain threshold, it has diminishing returns (Schenk, 2009). Jigging of material during welding is necessary to make sure the flatness where the main function is to hold and retain the component in the rigid alignment. It is important for the designed jig to have the ability to provide good access of welding, to be rigid and robust (G.hoffman).

The main consideration during designing welding jig is the clamping system, whether it is user friendly or not. User friendly clamping systems are those which can be clamped and released easily without consuming too much time in order to prevent material deformation. The distortion of material due to clamping and weld squeezing is calculated in the displacement-based finite formulation:

$$\{F\} = [K]\{\delta\} \tag{2.1}$$

Clamping system is one of the parameter that affect distortion and it is an important aspects since clamping system is always needed in welding operation in order to fix the workpiece. Mitigation methods had been developed for the purpose of reducing distortion by using different approaches such as LSND welding (Q. Guan Dang, 1994; Aa, 2007) (Aa, 2007), thermal tensioning (P. Michaleris, 1999; M. Deo, 2003), pre-deformation (Masubuchi, 1980) or by using optimized welding sequence (C. L. Tsai, 1999) (M. Mochizuki M. Hayashi, 2000; M.H Kadivar, 2000). The used of clamp as an in-line distortion mitigation technique will caused probable advantage where there will be no energy consuming technique will be introduced further in the process.

Influence of clamps mechanically had been studied mathematically on overlap joint and the result showed that distance of clamping have crucial influence on deformation. Other than that, by referring to the research, the closer the clamps, the less distortion will occur (S. Roeren, 2006). Josseran et. al. (E. Josserand, 2007) obtains result that showing the rate of cooling at the weld seam can affects the clamps and thermal contact condition.

## 2.5 MILD STEEL

Steel is any alloy of iron which consist 0.2% to 2.1% of carbon which act as hardening agent. Other metals that are used as hardening agent are chromium, manganese, tungsten and vanadium. Instead of the maximum limit of 2% of carbon in the manufacture of carbon steel, the proportions of manganese is 1.65%, both carbon and silicon 0.6% each are fixed. Meanwhile, the proportions of cobalt, chromium, niobium, molybdenum, titanium, nickel, tungsten, vanadium and zirconium are not fixed. Mild steel or also known as mildest grade of carbon is a typically carbon steel which contain a low amount of carbon which is 0.05% to 0.26%. Mild steel has high machinability which is rated at 55% to 60% and can be easily shapes due to its inherent flexibility. This type of steel can be hardened by carburizing to make it as an ideal material to produce range of consumer products. Mild steel possesses good formability, good weld ability and the cost of mild steel is comparatively low compare to the other steel.

## 2.6 STAINLESS STEEL

Stainless steel is not a new discovery but in facet are old materials that have been found in many products to ease human lives (Ali Bin Hamzah,1997). The demand of material is increasing by time and the criteria that are looked inside the material are such as lightweight, high strength, low cost and varied uses. These are the reason why scientist and material engineers put double efforts in producing materials with criteria of good or better than the previous one.

Stainless steel is alloy with a high percentage of chromium that is not less than 10.5%. Rust resistant is there because there is an oxide of chromium on the surface of the steel. Other elements are also mixed in order to improve abrasive resistant, fabrication and machinability and strength for examples nickel, molybdenum, cuprum titanium, silicon, manganese, columbium, aluminum, nitrogen and sulphur (Zainal Abidin Ahmad et al., 1999).

Stainless steel is being chosen based on rust and heat resistant, mechanical properties, fabrication abilities, availability and cost. Mostly, rust resistant and mechanical properties are the main factor for choosing stainless steel (Cam and Kocak, G. et al.,1998).

## 2.7. TAGUCHI METHOD

In the experiment planning, Taguchi technique is applied as it has become a powerful tool in improving productivity during research and development. This is to obtain a high quality product which can be product quickly by using low cost. This method is developed by Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan. This method is developed based on 'ORTHOGONAL ARRAY' experiment which give reduced 'variance' for the experiment with optimum settings of control parameters.

The marriage of Design of Experiments with optimization of control parameters to obtain best result is achieved in the Taguchi Method 'Orthogonal Arrays' (OA) is provide a set of well balance (minimum) experiments and Dr. Taguchi's Signal-to-Nose ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results. There are 3 Signal-to-Noise ratios of common interest for optimization:

(i) Smaller-The-Better

$$\mathrm{n}=-10\log_{10}[\text{mean of sum squares of measured data}] \quad (2.2)$$

(ii) Larger-The Better

$$\mathrm{n}=-10\log_{10}[\text{mean of sum squares of reciprocal of measured data}] \quad (2.3)$$

(iii) Nominal-The-Best

$$\mathrm{n}=-10\log_{10}\frac{\text{square of mean}}{\text{variance}} \quad (2.4)$$

# CHAPTER 3

# METHODOLOGY

## 3.1 INTRODUCTION

This project is done by performing experiment by using MIG welding machine. This experiment is about to join dissimilar welding and do testing on the weldability through visual appearance and by using Vickers hardness test. Before testing is conducted numbers of steps started with welding and followed by the sample preparation is done and is explained in detail in this chapter. Figure 3.1 shows the flow chart on the research methodology. The flowchart of this study is as presented in Appendix H.

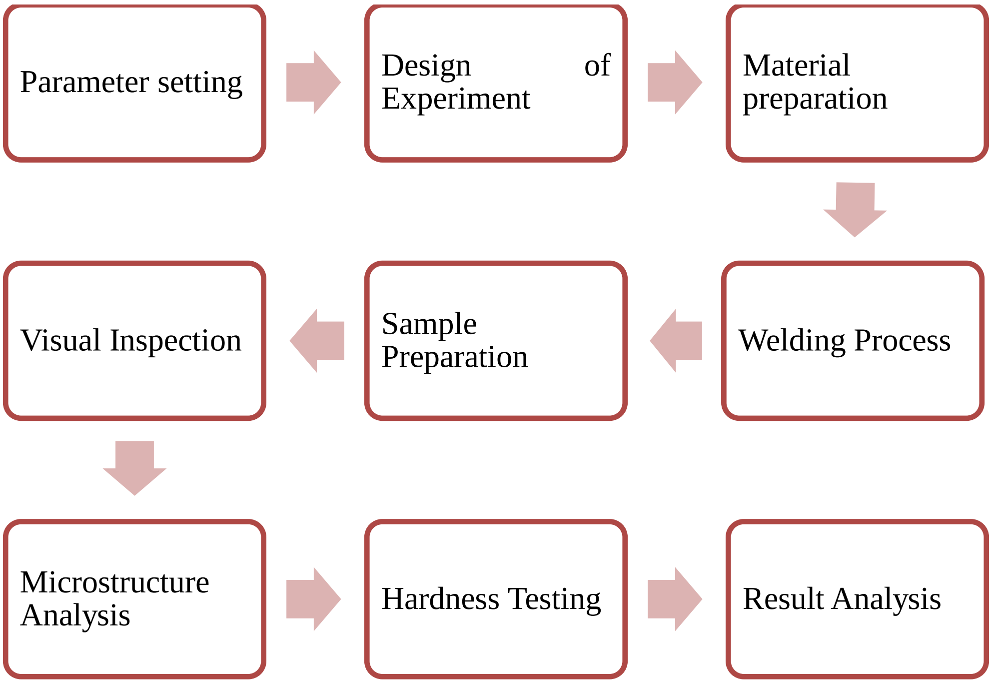


**Figure 3.1** Flow chart

## 3.2 PARAMETER SETTING

In order to find out the effect of clamping distance and voltage changes on the weldabilty on dissimilar welding, the current and speed is remain constant. This is due to the significant effect causes by current and the speed. The table below shows the welding parameters used in the experiment.

**Table 3.1:** Welding Parameters

| **Welding Parameter** | |
|---|---|
| Welding Current (A) | 95 A |
| Welding Speed (mm/s) | 4mm/s |
| Gas | 99.999% Argon |
| Filler wire | ER308 wire |

### 3.2.1 Material dimension and welding joint configuration

(A) Material dimension

The materials involved in this study are stainless steel and mild steel. These materials are widely used in automotive industry. The materials are 3mm in thickness and are cut in the dimension of 50mm×50mm. The material is cut by using shearing machine (NS Guillotine Searing) as shown in Figure 3.2.The machine setting is depending on the type of material to be cut.


**Figure 3.2**: Shearing Machine (Model type MVS-C 6/31)

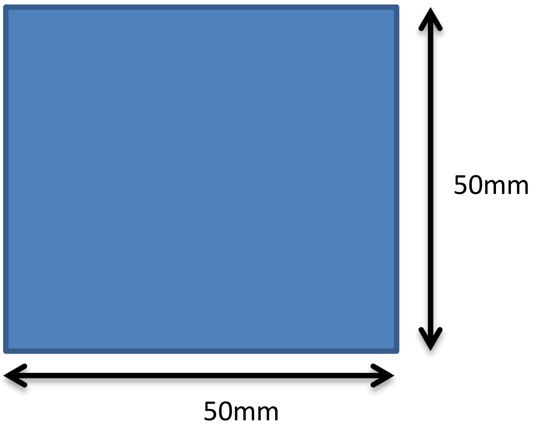


**Figure 3.3:** Material Dimension